DIATOMS IN RECENT BOTTOM SEDIMENTS AND TROPHIC STATUS OF EIGHT LAKES AND RESERVOIRS IN NORTHEASTERN UTAH

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Abstract.— Recent bottom sediments of eight lakes and reservoirs in northeastern Utah were examined. One hundred and sixty-four diatom taxa were identified and their relative abundances determined. Seven stand associations were evident by cluster analysis of similarity indices. These association patterns mirrored trophic status of the waters. Shannon-Wiener species diversity values were also determined. The diversities fell in patterns that were similar to the stand associations determined by cluster analysis. The most prevalent diatom taxa encountered in this study were found mostly in eutrophic waters. These taxa included *Stephanodiscus astraea*, *Stephanodiscus astraea* var. *minutula*, *Asterionella formosa*, and *Fragilaria crotonensis*. A wide variety of other taxa dominated various mesotrophic and oligotrophic sites.

A large literature on paleodiatomological investigations is extant, but few publications deal with diatoms in recent sediments (Kaczmarska 1976). Stockner and Benson (1967) examined diatom succession in recent sediments of Lake Washington. Stockner (1971) developed a classification scheme for deep water lakes, based on the A/C ratio (A = Araphidinae; C = Centrales) of diatoms in recent bottom sediments and plankton. Nevertheless, he commented that his scheme did not adequately characterize the current trophic state of shallow isothermal lakes or man-made reservoirs (Stockner 1972). Duthie and Sreenivasa (1972) studied the horizontal distribution of diatoms in recent sediments of Lake Ontario and attempted to correlate the results with chemical and other environmental factors. They also examined the relationship between the sedimentary diatom flora and the planktonic flora. Bortleson and Lee (1975) looked for evidence of cultural eutrophication from recent sediment layers in lakes. This study was more concerned with pronounced changes in chemical stratigraphy than diatom deposition and floristics.

Biological systems are most sensitive to the effects of pollution on the environment; yet, until recent years, biological studies have played a minor role in water quality assessment. Diatoms have been especially neglected in these studies. Cairns and Dickson (1971) have listed several factors contributing to this neglect. In the last 10 years, however, diatoms have been studied more thoroughly with respect to water quality and have graduated to a position of importance.

For several years in our laboratory we have pursued studies of the use of diatoms to assess water quality and trophic status of lakes, reservoirs, and streams throughout the intermountain west of North America (Merritt et al. 1977a, 1977b). Through such work, we have come to believe that diatom assemblages found in recent bottom sediments offer an attractive and important index of lake and reservoir ecology. The objectives of the present study were: (1) to determine the diatom species present in recent bottom sediments in several lakes and reservoirs in Utah, (2) to determine if diatoms found in the bottom sediments reflect the trophic status of such waters, and (3) to attempt to determine which species or groups of species are indicators of trophic status by using statistical analyses to correlate with known chemical and physical parameters associated with the lakes.

Site Descriptions

Eight lakes and reservoirs were selected for study. These lakes were selected for analysis as part of Environmental Protection Agency Program 208 Areawide Water Quality Studies. Research reports of these studies

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classified these lakes as oligotrophic, mesotrophic, and eutrophic (Environmental Protection Agency 1976, Merritt et al. 1977a, 1977b). The trophic status of each lake and reservoir was determined by assessing all environmental data available, including floristics, standing crop, water chemistry, etc. Table 1 summarizes lake or reservoir morphometry. The following site descriptions briefly characterize each lake or reservoir studied (Fig. 1). More detailed descriptions can be found in Merritt et al. (1977a, 1977b).

Steinaker Reservoir

Steinaker Reservoir is on Steinaker Draw, a tributary of Ashley Creek approximately 6 km north of Vernal, Uintah County, in eastern Utah. It has been classified as an oligo-mesotrophic system, tending more toward mesotrophy. The reservoir is relatively shallow, with a mean depth of 14.2 m and is fairly productive. Seasonal patterns and demand for irrigation water produce a widely fluctuating water level. The shallow depth results in a fairly large littoral zone. Bottom sediments were collected from two sites (Merritt et al. 1977b).

Starvation Reservoir

Starvation Reservoir is in northeastern Utah in Duchesne County on the Strawberry River, which is a tributary of the Duchesne River. Duchesne township is approximately 5 km southwest of the lake. Merritt et al. (1977b) classified this lake as a mesotrophic system. Their data suggest that the reservoir is maintaining its mesotrophic condition. Starvation Reservoir fluctuates widely in depth due to utilization of its water for irrigation. Samples were collected from two sites (Merritt et al. 1977b).

Moon Lake

Moon Lake is situated near Mountain Home, Duchesne County, Utah, and is fed by the Lakefork River. This lake is a high-mountain oligotrophic system. The lake is used for irrigation and recreation. Bottom sediments were collected from one site near the dam (Merritt et al. 1977b).

Strawberry Reservoir

Strawberry Reservoir is located on the Strawberry River in Wasatch County, Utah. It is situated in a valley east of the Wasatch Range and is approximately 40 km due east of Provo. Next to Utah Lake, this is the largest body of water in this study. This reservoir has always been a highly productive system, which is reflected in its classification as eutrophic with definite anoxic conditions below 6 m. It is older than the other reservoirs in our study. The deeper regions of the lake exceed 18 m, although overall it is fairly shallow, averaging about 9 m. Nineteen samples were collected from all parts of the lake

Table 1. Summary of morphometric data of lakes and reservoirs examined during this study.

	Strawberry Reservoir	Deer Creek Reservoir	Rockport Reservoir	Steinaker Reservoir	Starvation Reservoir	Echo Reservoir	Utah Lake	Moon Lake
Surface area (km^2)	34.2	11.3	4.8	3.3	13.4	5.9	385.1	3.1
Volume (x10^6m^3)	357.8	193.9	93.4	47.1	206.4	91.2	1108.0	44.1
Mean depth (m)	10.5	18.4	19.4	14.2	15.4	15.5	2.9	14.2
Maximum depth (m)	18.6	41.8	45.7	42.1	44.8	33.5	4.3	20.1
Spillway elevation (m)	2303	1651	1843	1677	1683	1694	1368	2470
Mean annual precipitation (cm)	54	54	40	20	19	36	46	43
Drainage area (km^2)	440	1450	828	54	1554	2745	6876	276
*Mean hydraulic retention time (yrs)	4.5	0.6	0.6	2.0	1.9	0.4	2.5	0.4

*Based on outflow.

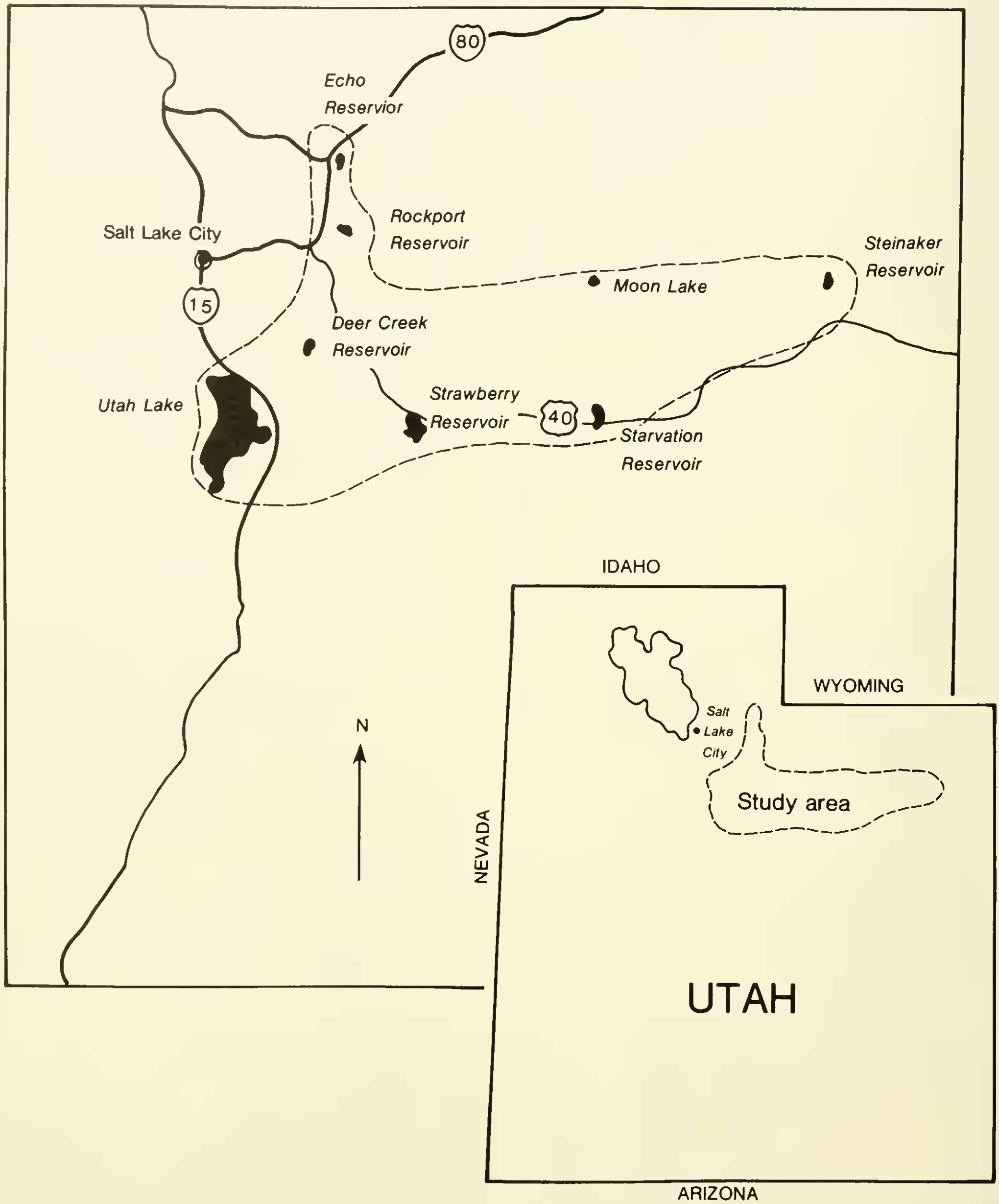

Fig. 1. Map of Utah showing the location of the lakes and reservoirs in the study area.

(Mountainland Association of Governments 1977a, 1977b).

Echo Reservoir

Echo Reservoir was formed on the Weber River in Summit County, Utah, immediately north of the town of Coalville. This reservoir is presently classified as eutrophic by Merritt et al. (1977a). Recent algal productivity figures indicate that the lake is mesotrophic even though other parameters indicate eutrophy (Merritt et al. 1977a). Similar to most of the lakes considered in our study, Echo Reservoir is subject to a heavy drawdown in dry years as a result of irrigation. Six sites were selected for collections (Mountainland Association of Governments 1977a, 1977b).

Rockport Reservoir

Rockport Reservoir was formed by damming the Weber River, Summit County, Utah, approximately 15 km upstream (southeast) from Echo Reservoir. The town of Peoa is about 8 km south of the lake, and Wanship is about 3 km north of the dam. This reservoir is not subjected to as heavy a drawdown as Echo Reservoir, although it is also used for storage of irrigation water. There is also a small municipal demand for this water. The reservoir was classified as mesotrophic to eutrophic. Five collection sites were established on Rockport Reservoir (Mountainland Association of Governments 1977a, 1977b).

Deer Creek Reservoir

Deer Creek Reservoir is on the Provo River approximately 7 km southwest of the town of Heber in north central Utah in Wasatch County. Not only is it a major water storage site for irrigation, but it also supplies culinary water for several municipalities. The north part of the lake is shallow and eutrophic, and the south part of the lake is deeper, with a lower standing crop, and meso-eutrophic in nature (Merritt et al. 1977a). Ten collection sites were established (Mountainland Association of Governments 1977a, 1977b).

Utah Lake

Utah Lake is at the mouth of the Provo River in an intermountain basin, bounded on the west by Lake Mountain and on the east by the Wasatch Mountains (Bolland 1974). It is the largest freshwater lake in Utah and is a natural reservoir. With increasing population, it has become a site for dumping industrial, municipal, and agricultural waste waters. This lake has been classified both as a highly eutrophic freshwater lake and as a moderately saline desert or prairie lake. Samples of recent bottom sediments were collected by following the transects established by Whiting et al. (1978). Eight collection sites were established (Mountainland Association of Governments 1977a, 1977b).

Methods

Field and Laboratory

Samples were collected from recent bottom sediments using an Eckmann dredge sampler. Collections were made between May and August of 1975 except for two samples collected in February 1976. Sediment samples were transferred to 250 ml plastic jars and returned to the laboratory for processing. Permanent diatom slides were prepared following standard nitric acid oxidation methods (St. Clair and Rushforth 1977) and were mounted in Naphrax diatom mountant. Slides were examined and diatom species identified under 1000 X with Ziess RA microscopes.

Data Analyses

Quantitative data on the diatom species were recorded by counting approximately 400 diatoms from each sample. These results were converted into percent relative density values for all species for each site. Shannon-Wiener diversity indices were calculated for individual samples (Margalef 1958).

Similarity indices were computed from relative density data for each stand relative to all other stands (Ruzicka 1958). Stand cluster analyses (Sneath and Sokal 1973) from similarity indices were performed to identify if and where unique communities occurred within and between each individual lake and reservoir. This clustering technique computes the average similarity of each stand to each other stand using arithmetic averages. It has been found to introduce less distortion than other methods (Kaesler and Cairns 1972). Lakes were also clustered to identify possible unique lake associations. This was done by averaging percent relative density for each species in all stands of each lake or reservoir and comparing the degree of similarity between any two waters. Cluster patterns among our reservoirs and lakes with known trophic states were used to determine if the diatoms in the recent bottom sediments significantly differ in lakes of different trophic states.

The most important diatoms in the study as a whole and the diatoms most important in stand clusters were determined using an importance index. This index was calculated by multiplying frequency times percent relative density (Warner and Harper 1972). Distribution of important diatoms along trophic level gradients was evaluated to determine broadly niched, tolerant species and restricted species.

Results and Discussion

One hundred and sixty-four diatom taxa were identified and their occurrence and relative density in 53 samples were noted. The most abundant organisms were planktonic species of *Stephanodiscus, Fragilaria, Melosira*, and *Asterionella*. Still, over 90 percent of all species were nonplanktonic diatoms. Table 2 contains a phylogenetic list of all diatoms identified.

Diatoms were ranked by importance values (Warner and Harper 1972) for all stands as well as for each lake and reservoir (Table 3). The most prevalent diatom taxa in this study were *Stephanodiscus astraea*, *Stephanodiscus astraea* var. *minutula*, *Asterionella formosa*, *Fragilaria crotonensis*, and *Stephanodiscus niagarae*. In addition, the following diatoms were locally important: *Achnanthes minutissima* was common in the mesotrophic, saline-eutrophic, and oligotrophic systems, and *Melosira granulata* was common in the mesotrophic and mildly eutrophic samples. *Diatoma vulgare* and *Cymbella affinis* were dominant in certain local areas of Rockport Reservoir and certain sites in Utah Lake. *Epithemia sorex* and *Cyclotella bodanica* were common in Steinaker Reservoir but were otherwise restricted in importance. Utah Lake was dominated by *Stephanodiscus astraea* var. *minutula* and *Melosira granulata* var. *angustissima*, and contained significant numbers of *Cyclotella meneghiniana*. *Nitzschia palea* and *Navicula cryptocephala* var. *veneta* were found commonly in the study area but were highest in occurrence in Moon Lake. *Achnanthes lanceolata* var. *dubia*, *Navicula cryptocephala*, *Navicula pupula*, and *Caloneis bacillum* were also common only in Moon Lake.

The results of our lake and reservoir cluster are presented in a dendrogram (Fig. 2).

TABLE 2. Phylogenetic list of diatom taxa found in recent bottom sediments of the selected lakes and reservoirs examined during this study.

COSCINODISCACEAE
Cyclotella bodanica Eulenst.
Cyclotella kutzingiana Thwaites
Cyclotella meneghiniana Kutzing
Cyclotella ocellata Pantocsek
Melosira granulata (Ehr.) Ralfs
Melosira granulata var. *angustissima* Mueller
Melosira varians Agardh
Stephanodiscus astraea (Ehr.) Grunow
Stephanodiscus astraea var. *minutula* (Kutz.) Grunow
Stephanodiscus niagarae Ehrenberg

FRAGILARIACEAE
Asterionella formosa Hassall
Diatoma anceps (Ehr.) Kirchner
Diatoma hiemale var. *mesodon* (Ehr.) Grunow
Diatoma tenue var. *elongatum* Lyngbye
Diatoma vulgare Bory
Diatoma vulgare var. *grande* (W.Sm.) Grunow
Fragilaria brevistriata Grunow
Fragilaria brevistriata var. *inflata* (Pant.) Hustedt
Fragilaria capucina var. *mesolepta* Rabenhorst
Fragilaria construens (Ehr.) Grunow
Fragilaria construens var. *binodis* (Ehr.) Grunow
Fragilaria construens var. *venter* (Ehr.) Grunow
Fragilaria crotonensis Kitton
Fragilaria leptostauron (Ehr.) Hustedt
Fragilaria leptostauron var. *dubia* (Grun.) Hustedt
Fragilaria pinnata var. *lancettula* (Schum.) Hustedt
Fragilaria vaucheriae (Kutz.) Petersen
Hannaea arcus (Ehr.) Patrick
Meridion circulare (Gr.) Agardh
Opephora martyi Heribaud
Synedra acus Kutzing
Synedra amphicephala Kutzing
Synedra capitata Ehrenberg
Synedra cyclopum Brutschy
Synedra cyclopum var. *robustum* Schultz
Synedra delicatissima W. Smith
Synedra parasitica var. *subconstricta* (Grun.) Hustedt
Synedra rumpens Kutzing
Synedra rumpens var. *fragilariodes* Grunow
Synedra socia Wallace
Synedra ulna (Nitz.) Ehrenberg
Synedra ulna var. *contracta* Oestrup
Tabellaria flocculosa (Roth) Kutzing

EUNOTIACEAE
Eunotia arcus var. *bidens* Grunow

ACHNANTHACEAE
Achnanthes exigua Grunow
Achnanthes hungarica Grunow
Achnanthes lanceolata (Breb.) Grunow
Achnanthes lanceolata var. *dubia* Grunow
Achnanthes linearis (W.Sm.) Grunow
Achnanthes minutissima Kutzing
Cocconeis disculus Schumann
Cocconeis pediculus Ehrenberg
Cocconeis placentula Ehrenberg

Table 2 continued.

Cocconeis placentula var. *euglypta* (Ehr.) Cleve
Cocconeis placentula var. *lineata* (Ehr.) v. Heurck
Rhoicosphenia curvata (Kutz.) Grunow

NAVICULACEAE
Caloneis amphisbaena (Bory) Cleve
Caloneis bacillum (Grun.) Cleve
Caloneis fenzlii (Grun.) Patrick
Caloneis lewisii Patrick
Diploneis elliptica (Kutz.) Cleve
Diploneis smithii (Breb.) Cleve
Frustulia vulgaris Thwaites
Gyrosigma acuminatum Kutzing
Gyrosigma macrum (W.Sm.) Griff. and Henfr.
Navicula anglica Grunow
Navicula arvensis Hustedt
Navicula bacillum Ehrenberg
Navicula bicephala Hustedt
Navicula capitata Ehrenberg
Navicula capitata var. *hungarica* (Grun.) Ross
Navicula circumtexta Meist. ex Hustedt
Navicula cryptocephala Kutzing
Navicula cryptocephala var. *veneta* (Kutz.) Rabenhorst
Navicula cuspidata (Kutz.) Kutzing
Navicula exigua var. *capitata* Patrick
Navicula graciloides A. Mayer
Navicula gysingensis Foged
Navicula lanceolata (Ag.) Kutzing
Navicula laterostrata Hustedt
Navicula minima Grunow
Navicula oblonga (Kutz.) Kutzing
Navicula pelliculosa (Breb. ex Kutz.) Hilse
Navicula pseudoreinhardtii Patrick
Navicula pupula Kutzing
Navicula pupula var. *rectangularis* (Greg.) Grunow
Navicula pygmaea Kutzing
Navicula radiosa Kutzing
Navicula radiosa var. *tenella* (Breb. ex Kutz.) Grunow
Navicula reinhardtii (Grun.) Grunow
Navicula rhyncocephala Kutzing
Navicula salinarum Grunow
Navicula salinarum var. *intermedia* (Grun.) Cleve
Navicula secreta Krasske
Navicula seminulum Grunow
Navicula tripunctata (O. Muel.) Bory
Navicula variostriata Krasske
Navicula viridula Kutz. em v. Heurck
Navicula viridula var. *avenacea* (Breb. ex Grun.) v. Heurck
Neidium binode (Ehr.) Hustedt
Neidium dubium (Ehr.) Cleve
Neidium iridis (Ehr.) Cleve
Pinnularia biceps Gregory
Pinnularia brebissonii Kutzing
Pinnularia viridis (Nitz.) Ehrenberg
Pinnularia viridis var. *minor* Cleve
Pleurosigma australe Grunow
Pleurosigma delicatulum W. Smith
Stauroneis anceps Ehrenberg
Stauroneis anceps var. *gracillis* Rabenhorst
Stauroneis anceps var. *linearis* (Ehr.) Cleve
Stauroneis phoenicenteron Ehrenberg
Stauroneis smithii var. *incisa* Pantocsek

Table 2 continued.

CYMBELLACEAE
Amphora ovalis Kutzing
Amphora ovalis var. *pediculus* Kutzing
Amphora perpusilla Grunow
Amphora veneta Kutzing
Cymbella affinis Kutzing
Cymbella cistula (Hemp.) Grunow
Cymbella delicatula Kutzing
Cymbella gracilis (Rabh.) Cleve
Cymbella mexicana (Ehr.) Cleve
Cymbella microcephala Grunow
Cymbella prostrata (Berk.) Cleve
Cymbella sinuata Gregory
Cymbella ventricosa Kutzing

GOMPHONEMACEAE
Gomphoneis herculeana (Ehr.) Cleve
Gomphonema acuminatum Ehrenberg
Gomphonema angustatum (Kutz.) Rabenhorst
Gomphonema constrictum Ehrenberg
Gomphonema gracile Ehrenberg
Gomphonema intricatum Kutzing
Gomphonema intricatum var. *pumila* Grunow
Gomphonema olivaceum (Lyng.) Kutzing
Gomphonema parvulum Kutzing

EPITHEMIACEAE
Denticula elegans Kutzing
Epithemia argus Kutzing
Epithemia sorex Kutzing
Epithemia turgida (Ehr.) Kutzing
Epithemia adnata (Kutz.) Brebisson
Rhopalodia gibba (Ehr.) O. Mueller
Rhopalodia gibba var. *ventricosa* (Kutz.) Peragallo
Rhopalodia gibberula (Ehr.) O. Mueller

NITZSCHIACEAE
Bacillaria paradoxa Gmelin
Hantzschia amphioxys (Ehr.) Grunow
Nitzschia amphibia Grunow
Nitzschia angustata (W.Sm.) Grunow
Nitzschia dissipata (Kutz.) Grunow
Nitzschia fonticola Grunow
Nitzschia frustulum Kutzing
Nitzschia hungarica Grunow
Nitzschia linearis W. Smith
Nitzschia palea (Kutz.) W. Smith
Nitzschia punctata (W.Sm.) Grunow
Nitzschia sigmoidea (Ehr.) W. Smith
Nitzschia tryblionella var. *levidensis* Hantzsch
Nitzschia species

SURIBELLACEAE
Cymatopleura elliptica (Breb.) W. Smith
Cymatopleura solea (Breb.) W. Smith
Surirella angustata Kutzing
Surirella ovalis Brebisson
Surirella ovata Kutzing
Surirella robusta Ehrenberg
Surirella spiralis Kutzing

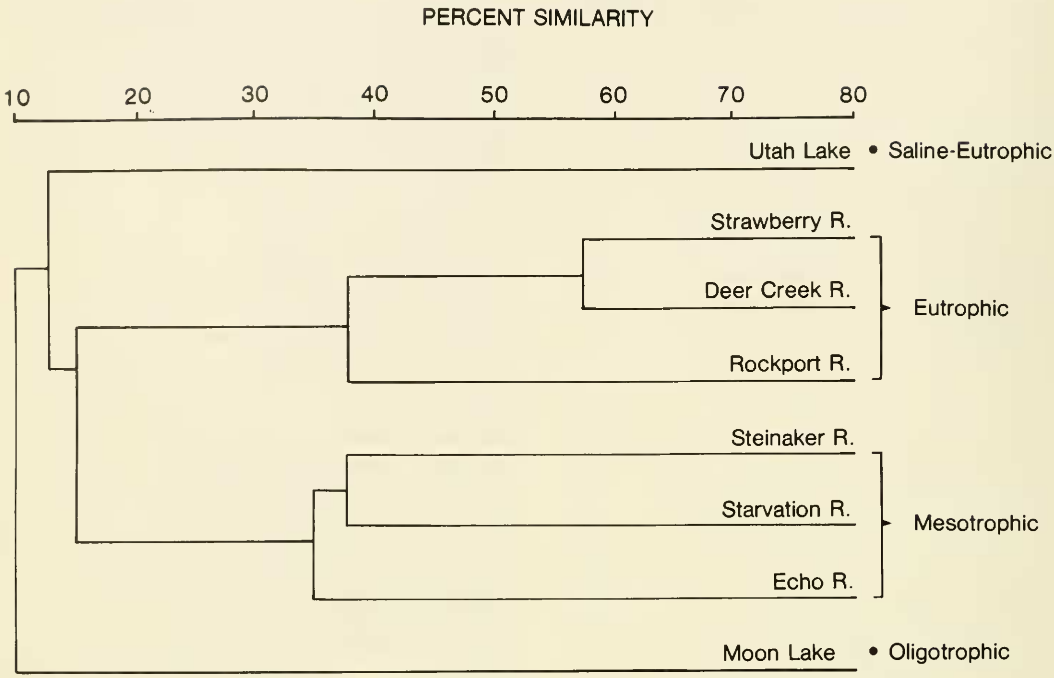

Fig. 2. Cluster dendrogram showing similarities between stands from different lakes and reservoirs.

The cluster pattern supported previous evidence for the general trophic status of each lake and reservoir (Merritt et al. 1977a, 1977b). The eutrophic Strawberry and Deer Creek reservoirs clustered fairly tightly, with 58% similarity. Rockport Reservoir, a meso-eutrophic system, clustered with these two but at a lower level of similarity (38%). The mesotrophic Steinaker, Starvation, and Echo reservoirs clustered together fairly loosely at about 36% similarity. These reservoirs are at various levels of mesotrophy and each has a potential for rapid eutrophy. Utah Lake is a large, slightly saline eutrophic lake with little similarity to the other waters studied. The same is true for the oligotrophic Moon Lake.

The results of clustering our 53 stands are presented in Figure 3. Four major clusters and seven subgroups are evident in this dendrogram. The cluster pattern, based on species occurring in each stand, yielded groups representative of various degrees of eutrophication. In addition, species diversity of diatom populations, as measured by the Shannon-Wiener index, correlated with the trophic status of the collection sites (Fig. 4). The majority of our stands reflect the current view that oligotrophic or somewhat mesotrophic waters tend to support highly diverse floras, and more eutrophic waters support less diverse floras. For example, some samples from highly eutrophic sites with a very low species diversity contained only a few tolerant species. These samples tended to be highly similar and cluster tightly (Fig. 3). Certain stands in Strawberry Reservoir consisted of only four to six species with Shannon-Wiener diversity values of only 0.37 to 0.93 (Fig. 4). Such stands were as much as 89% similar. Other stands in the study area showed the opposite extreme. They had high species diversity, with as many as 60 species per stand. This produced Shannon-Wiener values above 3.0. Such stands occurred in oligotrophic sites. It is interesting that these oligotrophic stands showed much less similarity to one another (less than 28%) than the eutrophic stands.

Subgroup I (Fig. 3) is composed of stands from eutrophic sites. It is composed mostly of stands from Strawberry Reservoir, together with two Deer Creek Reservoir and three Rockport Reservoir stands. *Stephanodiscus astraea* dominated all sites. Over 85% of the population of half of these sites resulted from this species alone, with its average abundance being 82.3% (Table 4). *Asterionella formosa*, *Hantzschia amphioxys*, *Melosira granulata*, and *Cocconeis placentula* var. *lineata* were common, each in a separate sample of this subgroup. Tightness of clusters and low species diversity set these 17 samples apart from the rest of the stands in the study. Environmental data show that these stands are the most eutrophic in the study.

Subgroup II (Fig. 3) is a discrete group of Deer Creek Reservoir samples. These sites are characterized by the dominance of *Stephanodiscus astraea* and *Asterionella formosa*. *Stephanodiscus niagarae* was also common in all sites except one where it was replaced by *Fragilaria crotonensis*. This group of Deer Creek samples represents sites from the southern part of the lake. Merritt et al. (1977a) divided Deer Creek into two environmental types, the northern half being eutrophic and the southern meso-eutrophic. The two samples from Deer Creek that clustered in subgroup I are from the northern half of the reservoir and follow the designated eutrophic state. The seven samples in subgroup II are moderately eutrophic.

Subgroup III (Fig. 3) is a discrete group of three samples from Strawberry Reservoir.

TABLE 3. Summary of prevalent species in the lakes and reservoirs examined during this study. Species with average relative densities above the 3% level were included.

	All lakes and reservoirs	Strawberry Reservoir	Deer Creek Reservoir	Rockport Reservoir	Steinaker Reservoir	Starvation Reservoir	Echo Reservoir	Utah Lake	Moon Lake
Stephanodiscus astraea	37.4	58.7	56.8	47.6			5.8	3.1	
Stephanodiscus astraea var. *minutula*	11.2	15.5			8.5	12.6	11.0	23.4	
Asterionella formosa	8.9	5.0	20.9		10.5	17.4	14.7		13.0
Fragilaria crotonensis	5.1		3.2		27.0	39.5	14.8		5.0
Stephanodiscus niagarae	4.1	4.4	5.9			9.3	3.6	4.1	
Cocconeis placentula var. *lineata*		3.7			3.5				
Melosira granulata			4.2			11.5	3.5		
Diatoma vulgare				10.1			3.2		
Achnanthes minutissima				5.7	4.0		5.1	6.5	5.0
Cymbella affinis				5.0					
Amphora venata				3.3					
Navicula cryptocephala var. *venata*				3.3			3.5		9.0
Nitzschia palea					3.5		4.5		11.0
Epithemia sorex					7.5				
Cyclotella bodanica					5.0				
Achnanthes lanceolata					4.5		3.6		
Surirella ovalis							5.0		
Gomphonema olivaceum							3.5		
Melosira granulata var. *angustissima*								17.9	
Cyclotella meneghiniana								9.7	
Amphora ovalis								4.5	
Pleurosigma delicatulm								3.3	
Amphora ovalis var. *pediculus*								3.2	
Achnanthes lanceolata var. *dubia*									8.0
Navicula cryptocephala									6.0
Navicula pupula									6.0
Calonies bacillum									5.0
Tabellaria flocculosa									4.0
Synedra amphicephala									4.0
Nitzschia frustulum									3.0
Nitzschia linearis									3.0

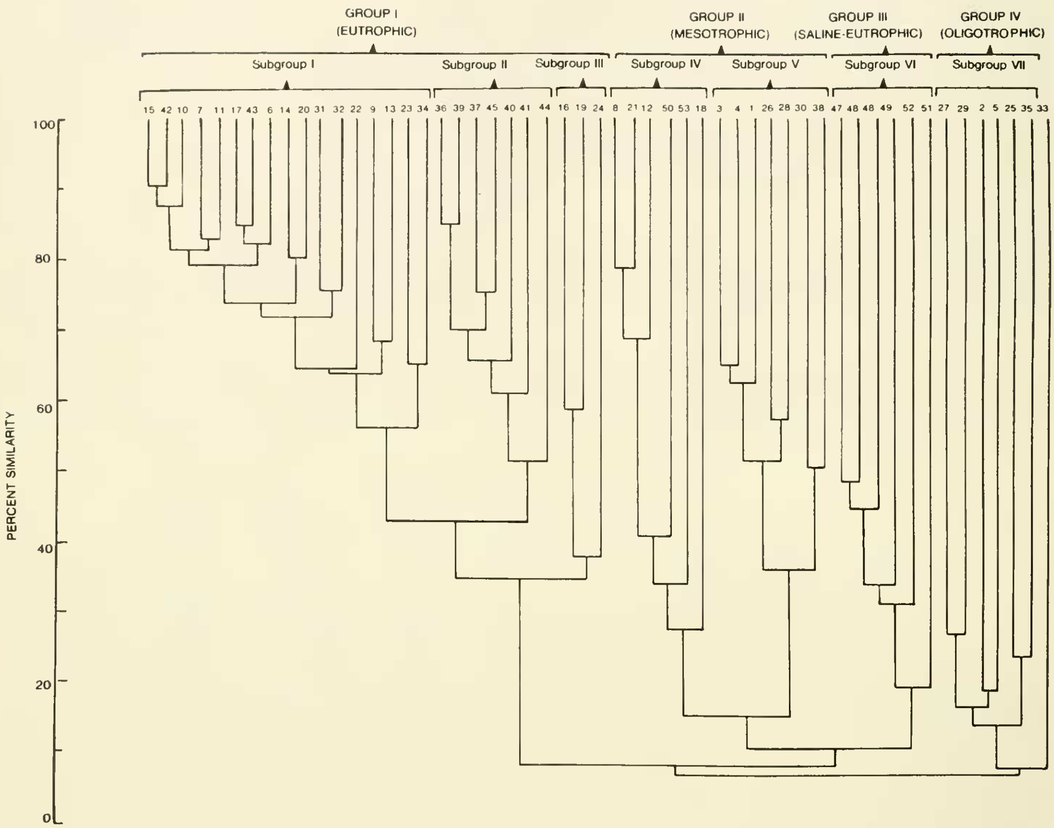

Fig. 3. Cluster dendrogram showing similarities of stands of diatoms in the study area. Sample numbers are shown within subgroups. An explanation of these numbers can be found in Table 5.

This unit is similar to Subgroup II. *Stephanodiscus astraea* is responsible for an average of 45% of the diatom populations. *Asterionella formosa* is replaced by *Cocconeis placentula* var. *lineata* in two of the samples and by *Nitzschia palea* and *Navicula lanceolata* in the third. These samples are probably meso-eutrophic stands in isolated parts of an otherwise highly eutrophic reservoir. For example, one of these samples was collected at the inlet of Strawberry River and would have a strong river influence that would isolate it from the surrounding reservoir type.

Subgroup IV (Fig. 3) is dominated by *Stephanodiscus astraea* var. *minutula*. Beyond this species, similarity between stands is relatively low. The subgroup is composed of three Strawberry Reservoir samples that are eutrophic and differ from subgroup I by having a variety of *Stephanodiscus astraea* as the dominant form. A fourth Strawberry Reservoir sample is uniquely dominated by *Stephanodiscus niagarae* and *Stephanodiscus astraea* var. *minutula*. The other two samples making up this subgroup were from Utah Lake. Their uniqueness is ascribed to the commonness of *Diatoma vulgare* in one sample and *Achnanthes minutissima* in the other. Both these samples differ strongly from the rest taken from Utah Lake. One was taken from Provo Bay, an isolated area with lower turbidity and TDS than the rest of the

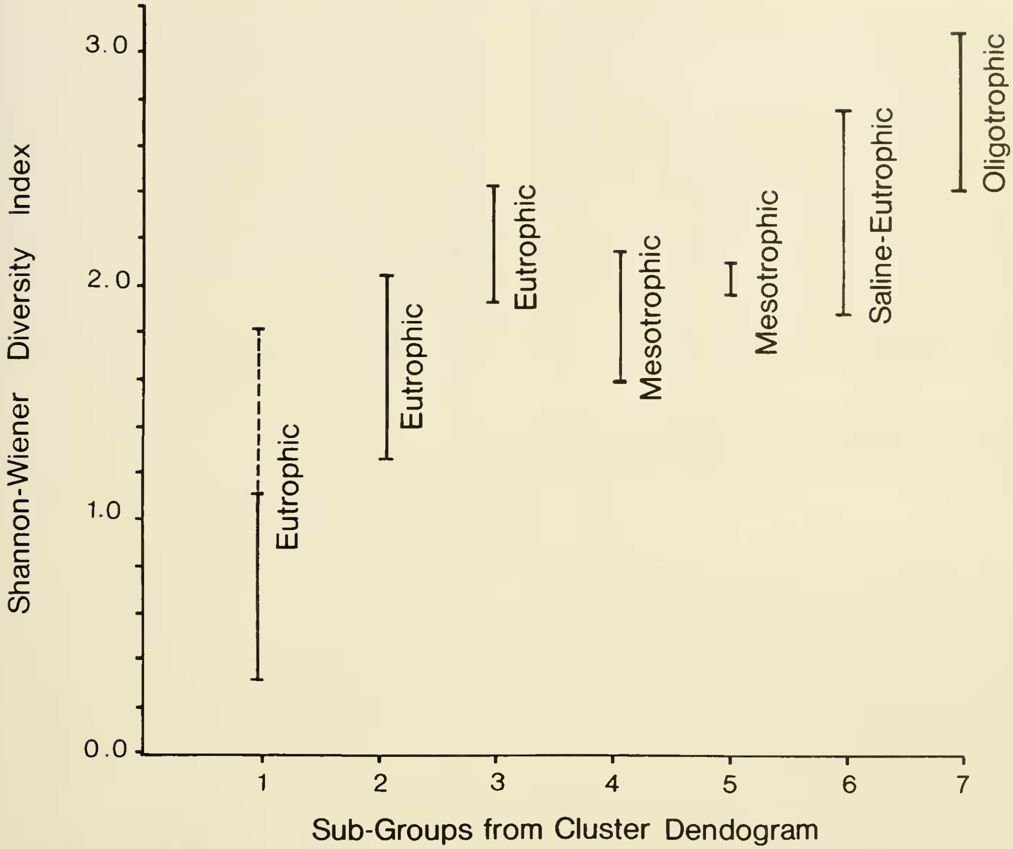

Fig. 4. Shannon-Wiener diversity indices for stands in relationship to subgroups described in the stand cluster dendrogram (Fig. 3). Subgroups I to III represent the eutrophic samples. Subgroups IV and V represent the mesotrophic sites, subgroup VI the saline eutrophic, and subgroup VII the oligotrophic.

lake. The other, from the west shore of the lake, was possibly influenced by one of the numerous underwater springs.

Subgroup V (Fig. 3) is not formed from stands from any particular lake. Except for one Deer Creek Reservoir sample, the stands are from mesotrophic systems. Diatoms that characterize this group are *Fragilaria crotonensis, Asterionella formosa, Stephanodiscus astraea* var. *minutula, Melosira granulata, Stephanodiscus niagarae,* and *Stephanodiscus astraea.* These organisms were present in less abundance than in the eutrophic groups, and diversity was higher (Fig. 4).

Subgroup VI (Fig. 3) is a discrete unit from Utah Lake. All the Utah Lake samples clustered together in this unit except for the two in subgroup IV. *Melosira granulata* var. *angustissima, Stephanodiscus astraea* var. *minutula,* and *Cyclotella meneghiniana* dominated this group. *Amphora ovalis, Stephanodiscus niagarae,* and *Achnanthes minutissima* were common in the majority of samples. This pattern of high diversity (Fig. 4) in an otherwise eutrophic system seems to be typical of saline eutrophic systems with high TDS and turbidity.

Subgroup VII (Fig. 3) is another unit of dissimilar samples. Each of these samples contained a diverse diatom flora (Fig. 4), and no single species or group of species dominated. Diatoms important in stands of this subgroup were *Achnanthes minutissima, Nitzschia palea, Asterionella formosa, Navicula cryptocephala* var. *veneta, Surirella ovalis, Achnanthes lanceolata, Gomphonema olivaceum,* and *Nitzschia amphibia.* Diversity was very high, as is common in oligotrophic systems (Fig. 4).

One sample from Rockport Reservoir did not cluster with any subgroup at all. The diatoms that characterized this sample were

Diatoma vulgare and *Cymbella affinis*. *Melosira varians* and *Gomphonema olivaceum* were also common. This stand did not cluster with subgroup II or III even though it also derives from moderately eutrophic waters.

This study supports the suggestion that diatom assemblages occurring in recent bottom sediments can accurately reflect current trophic conditions of the waters of deposition. Furthermore, the study of bottom sediment diatom assemblages can be extremely useful since sampling can be done during any season. Nevertheless, we view the study of recent bottom sediment diatoms as an important additional tool rather than a replacement of other biological, physical, and chemical analyses.

This conclusion is important for another reason. Paleodiatomological studies have long assumed that diatom assemblages in sediments have reflected the ecological status of depositional waters. The present study provides additional evidence that this assumption is valid.

To demonstrate the relationship between bottom sediment diatoms and planktonic

TABLE 4. Prevalent diatom species responsible for the formation of subgroups in Figure 2. The importance value is obtained by multiplying frequency by average relative density.

Species	Subgroup I	Subgroup II	Subgroup III	Subgroup IV	Subgroup V	Subgroup VI	Subgroup VII
Stephanodiscus astraea	82.3	51.0	44.6	9.6		3.3	2.3
Asterionella formosa	4.7	26.4	2.6	3.6	19.2		6.8
Stephanodiscus niagarae	1.5	6.1			7.9	5.5	
Melosira granulata	1.4	4.0		2.3	8.3		
Cocconeis placentua var. *lineata*	1.2		18.4				2.4
Hantzschia amphioxys	1.0						
Fragilaria crotonensis		2.3			32.5		
Achnanthes minutissima		1.7	2.6	4.5	1.2	4.1	10.4
Nitzschia palea			4.7		1.1		6.8
Navicula cryptocephala var. *veneta*			2.9	1.0			5.1
Epithemia sorex			2.7				
Fragilaria capucina var. *mesolepta*			2.6				
Navicula lanceolata			2.4				
Nitzschia amphibia			1.8				
Nitzschia frustulum			1.5				
Synedra socia			1.3				
Navicula pupula			1.2				
Synedra ulna			1.2				
Stephanodiscus astraea var. *minutula*				66.2	14.2	14.2	
Diatoma vulgare				1.0			2.8
Stephanodiscus astraea					7.6		
Cyclotella bodanica					1.6		
Melosira granulata var. *angustissima*						23.2	
Cyclotella meneghiniana						12.3	
Amphora ovalis						6.1	
Pleurosigma delicatulum						4.3	
Amphora ovalis var. *pediculus*						3.5	
Surirella ovalis						2.3	5.0
Navicula graciloides						1.5	
Diploneis smithii						1.1	
Nitzschia linearis						1.0	
Achnanthes lanceolata							4.8
Gomphonema olivaceum							3.2
Nitzschia amphibia							3.0
Amphora veneta							2.8
Cocconeis placentula var. *euglypta*							2.8
Cymbella ventricosa							2.5
Gomphonema parvulum							1.8

Table 5. Number of species encountered and Shannon-Wiener species diversity index for each sample studied. Sample codes refer to station numbers established by Mountainland Association of Governments (MAG 1977a) and Uinta Basin Association of Governments (Merritt et al. 1977a).

Sample number	Sample code	No. of species in sample	Species diversity index
	Steinaker Reservoir		
1	SN-2	14	1.58
2	SN-1	31	3.07
	Starvation Reservoir		
3	SR-3	10	1.72
4	SR-5	14	1.83
	Moon Lake		
5	M-2	31	3.02
	Strawberry Reservoir		
6	SB-1	15	0.74
7	SB-2	11	0.55
8	SB-3	6	0.37
9	SB-4	27	1.09
10	SB-5-1	22	0.54
11	SB-5-2	21	0.59
12	SB-5-3	5	0.74
13	SB-6-1	33	1.45
14	SB-6-2	16	0.83
15	SB-6-3	19	0.30
16	SB-6-4	39	1.93
17	SB-6-5	18	0.58
18	SB-6-6	4	0.93
19	SB-7	30	1.96
20	SB-9-1	22	1.03
21	SB-9-2	5	0.62
22	SB-9-3	15	0.96
23	SB-10	60	1.81
24	SB-11	39	2.41
	Echo Reservoir		
25	E-3	38	2.65
26	E-2	21	1.63
27	E-6	16	2.39
28	E-1	27	2.13
29	E-7	32	2.90
30	E-5	22	1.95
	Rockport Reservoir		
31	R-5	22	0.33
32	R-1	15	1.00
33	R-3	17	1.67
34	R-2	24	1.30
35	R-3.5	24	2.60
	Deer Creek Reservoir		
36	A-2	18	1.23
37	A-3	24	1.64
38	C-1	14	1.92
39	C-2	38	1.51
40	C-3	46	2.03
41	C-4	21	1.94
42	DC-14	16	0.40
43	DC-13	17	0.70
44	DC-15	35	1.86
45	DC-7	26	1.43
	Utah Lake		
46	UL-13.5	24	2.37
47	UL-13	27	2.72
48	UL-6	21	2.23
49	UL-26.5	21	1.89
50	PB-3	26	2.09
51	UL-3	18	1.99
52	UL-11	16	1.99
53	UL-12.5	23	1.95

floras, we are currently correlating the relative densities of the two in our study sites with physical and chemical parameters. Further research is planned in three areas. First, we want to assess the effects of in-lake diatom transport. Second, we want to determine the usefulness of recent bottom sediment diatom studies for determining small differences in trophic status in a single lake. And third, we are interested in pursuing the reason for dominance of centric diatoms in our eutrophic study sites in contrast to other forms elsewhere (Stockner 1972).

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